The World vs. SCOTT: Synthesis of COncealment Two-level Texture

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Abstract: We propose an original method of Synthesis of COncealment Two-level Texture (SCOTT). SCOTT was designed according to the Human Visual System so that the concealment texture is faithful to the visual environment it will be placed in, in terms of forms and colors. The results of simulation prove that the concealment texture is efficient although it is made of simple forms and only a few colors. Even if SCOTT has initially been designed for an application of reducing the visual pollution caused by manmade equipments (antenna, electrical cabinets, distributor boxes, repeater shelters, etc.), it may be used in many applications, such as inpainting, and even in image compression.

1 INTRODUCTION

We propose an original method of Synthesis of COncealment Two-level Texture (SCOTT), which provides a texture faithful to the visual environment it will be placed in, *while* having simple forms and only a few colors. The purpose of a concealment texture is to be both generic enough to be placed at different positions and viewpoints in a scene, and accurate enough to be efficient, at different scales. It is a trade-off between genericity and efficiency. Based on the Human Visual System, SCOTT synthesizes a "two-level texture" which is a mix between a macro-texture and a micro-texture. The macro-texture represents the global aspect of the concealment texture, i.e. its dominant forms. In case of a regular texture, the global aspect is given by the primitives, like the bricks of a brick wall. Similarly, the micro-texture represents the local aspect of the concealment texture, i.e. the details inside the dominant forms. In case of a regular texture, the local aspect is given by the random-like distribution of colors inside the primitives, like the appearance of "grain" at the surface of a brick. So the concept of "macro" and "micro" depends of the scale of observation. A macro-texture becomes a micro-texture when observed at a longer distance; on the contrary, a micro-texture becomes a macro-texture when observed at a shorter distance. This duality can be found in various natural (e.g. a pebble beach) and artificial (e.g. a brick wall) structures. In the case of a computer-generated texture, such a duality gives the texture a visual richness which makes it more realistic; we can compare the video games issued ten years ago, and those recently issued: the richness of the textures make them more "true". It is important to keep in mind that our goal is not to synthesize a texture exactly the same as a given visual environment; our need requires a trade-off between genericity and efficiency.

2 PROPOSED METHOD

SCOTT has been designed according to the the Human Visual System, and synthesizes a two-level texture, based on a mix of a macro-texture and a micro-texture. The fusion of these two levels of texture gives a realistic final texture, faithful to the visual environment it will be placed in.

2.1 Human Visual System

An object is concealed if it has the same dominant colors *and* the same dominant forms as its visual environment (Julesz, 1999). These two global concealment rules, having the same dominant colors *and* the same spatial frequency spectrum (dominant forms), are defined according how of the Human Visual System receives and processes the visual information. The visual information is borne by the "color", as a sum of visible frequencies. These electro-magnetic frequencies are received by the retina, and the color perceived by the brain depends on the frequency response of the rods and cones inside the retina. A user-friendly way to represent the perceivable colors is the HSV (Hue, Saturation, Value) colorspace. When one sees an object, the color information is processed in the primary visual cortex V1 to extract the color contrasts. These contrasts allow higher cortical areas to extract forms, which may finally be identified by even higher cortical areas (Buduc, 2012).

Then the HSV works like an interpreter, going from concrete low-level pieces of information, that is the electro-magnetic spectrum of the light received, to abstract high-level semantic concepts (e.g.: “a blue small car”).

So an object may be identified if there exists a contrast between this object and its visual environment, in terms of colors or the distribution of the colors (forms) (Landragin, 2004; Baumbach, 2010). In other words, an object will *not* be identified, nor detected, if it has the same colors, *and* the same forms (spatial frequency spectrum), as its visual environment.

Even if such a representation of the HSV remains very simplistic, its level of precision is enough for our need: it is not to create an exhaustive model of the HSV to make objects invisible (for the concealment of distributor boxes, it would indeed be difficult to maintain them if they cannot be located!), but to reduce the visual pollution by giving the “polluants” an aesthetically more pleasing look. For further information, the reader is invited to have a “look” at references (Julesz, 1999; Buduc, 2012; Landragin, 2004; Baumbach, 2010).

2.2 Synthesis of COncealment Two-level Texture

From our study of the Human Visual System, we defined two general concealment rules: “having the same dominant colors” *and* “having the same dominant forms”. SCOTT is then built around these two components: computing the *colors* and the *forms* (Julesz, 1999).

To make the concealment texture faithful to the visual environment it will be placed in, it is synthesized according to a two-level concept, like in the case of a brick wall: the global aspect of the walls, as a concatenation of bricks, is its *macro*-texture. So the macro-texture (coarse texture) corresponds to the dominant forms and colors of the concealment texture. And the local aspect of the wall, that is the details inside one particular brick, is its *micro*-texture. So the micro-texture (fine texture) corresponds to the secondary colors and forms of the concealment texture. In other words, the duality macro-texture/micro-texture can be viewed as the duality global/local appearance of the texture, depending on the scale considered.

We have to keep in mind that the purpose of a concealment texture is to be both generic enough to be placed at different positions in a scene, and accurate enough to be efficient, at different scales. It is a trade-off between *genericity* and *efficiency*.

So SCOTT computes the concealment texture from two input models: *one model* for the macro-texture (coarse texture) and *one model* for the micro-texture (fine texture); SCOTT first computes the macro-texture and the micro-texture independently, and then mixes them to synthesize the concealment texture (Figure 1). For the moment the two input models are selected manually, then the choice is subjective.

2.2.1 Synthesis of Macro-texture

The *macro*-texture, i.e. the dominant colors and forms of the concealment texture, represents the coarse texture of the concealment texture. The macro-texture makes the concealment efficient at long distances of observation. These colors and forms are computed from the macro-texture model. This model must be representative of the global aspect that the user wants the texture of dissimulation to look like. The computation of the macro-texture is divided into 3 steps (Figure 1):

1. **Extracting dominant colors.** From the L*a*b* histogram of the macro-texture model, the dominant colors are extracted. The L*a*b* colorspace has been chosen because it has been designed so that a Euclidian distance computated inside this colorspace corresponds to a visual distance. The number of dominant colors to extract depends on the colorimetric content of the macro-texture model.
2. **Extracting dominant forms.** The forms (regions) are extracted using a segmentation of the pixels of the same model. To do so, we use a k-means clustering (MacQueen, 1967) process based on the L*a*b* components of the pixels of the macro-texture model. The “clustering” effect in the L*a*b* colorspace is then equivalent to a segmentation in the image space, since the forms are perceived by the Human Visual System as contrasts of colors.
3. **Combining colors and forms** The dominant colors are combined with the dominant forms, by computing the Euclidian distances between the

dominant colors and the mean colors inside the dominant forms, in the L*a*b* colorspace. The combination is done in a way that each dominant form has a different dominant color and the MSE of the combination is minimized.

At this step we have a simple macro-texture with coarse forms and only a few colors, which makes the concealment efficient at long distances of observation.

2.2.2 Synthesis of Micro-texture

The *micro*-texture, i.e. the secondary colors and forms of the concealment texture, represents the fine texture of the concealment texture. Contrary to the the macro-texture which makes the concealment efficient at long distances of observation, the micro-texture makes the concealment efficient at short distances of observation. At medium distances, both macro-texture and micro-texture are efficient in their own role. This fine texture makes the concealment texture more faithful to the visual environment. The idea behind adding a fine texture to the coarse texture is to make the spatial frequency spectrum of the concealment texture more "rich" by adding high frequencies through random-like small forms; indeed the natural scenes generally have random-like small forms. The forms of the fine texutre are computed from the micro-texture model. The micro-texture model may be totally independent from the macro-texture model. The only requirement for this model is that it must be *stochastic*: sand, grass, etc. So the name of the game is to make the fine texture appear at short distances of observation, while preserving the forms of the macro-texture at long distances of observation, like in the case of a brick wall. The computation of the micro-texture is divided into 2 steps (Figure 1):

1. **Resizing the model.** The micro-texture model is resized to fit the size of the macro-texture. If the micro-texture model is bigger than the macro-texture, it is simply cropped. If it is smaller, a new model is synthesized with a patch-based synthesis (Finkelstein and Hoppe, 2000) using the micro-texture model: the model is divided into blocks called "patches", and a new texture (whose size is that of the macro-texture) is synthesized by randomly concatenating thoses patches.

2. **Extracting the dominant forms.** The dominant forms are extracted from the resized micro-texture model with the same process as for the macro-texture: k-means clustering. Theses forms must be superimposed on those of the macro-texture to mix both the macro-texture forms and the micro-texture forms.

2.2.3 Mixture of the Micro-texture with the Macro-texture

According to the behavior of the Human Visual System, a form is noticeable if its inner color contrasts with the colors around. So to mix the micro-texture with the macro-texture, we use this principle the other way around. Since we want the micro-texture to be visible above the macro-texture, we make the macro-texture colors, precisely the L* component in L*a*b* colorspace, vary according to the micro-texture forms. The micro-texture is used as a mask above the macro-texture and increases/decreases the L* component of the pixels in the macro-texture underneath.

The third step of SCOTT allows the micro-texture to be superimposed on the macro-texture, giving the final concealment texture a visual "richness" which makes it more realistic.

Finally, after the entire SCOTT process (Figure 2), we obtain a concealment two-level texture which is faithful to the visual environment it will be placed in, *while* having simple forms and only a few colors.

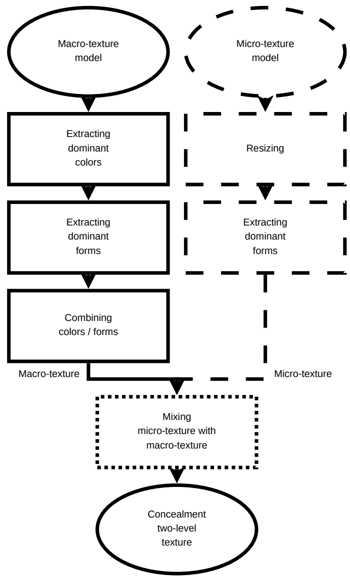
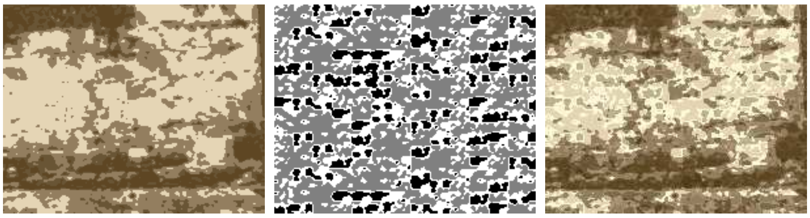


Figure 1: SCOTT is based on a "two-level" texture concept, mixing a micro-texture (dashed lines) with a macro-texture (solid lines), from two input models.

3 RESULTS OF SUBSTITUTION

SCOTT will then synthesize a texture faithful to the visual environment it will be placed in, *while* having simple forms and only a few colors. So far, the number of dominant colors needs to be manually adjusted

(a) Macro-texture model (b) Micro-texture model (c) Resized micro-texture model (d) Macro-texture dominant forms



(e) Macro-texture dominant forms with dominant colors (f) Resized micro-texture dominant forms (g) Final 2-level concealment texture

Figure 2: The concealment texture is based on a two-level concept. The concealment *macro*-texture corresponds to the coarse texture, and is synthesized from the first input sample (a). The dominant forms (d) and colors are combined (e). The concealment *micro*-texture corresponds to the fine texture, and is synthesized from the second input sample (b). The sample is resized (c) to fit the size of the concealment macro-texture. Then the dominant forms (f) are extracted to be mixed with those of the concealment macro-texture. The mixture is made by using the micro-texture dominant forms as a mask above the concealment macro-texture, and making the colors of the concealment macro-texture vary (brighter or darker), according to the micro-texture dominant forms above (g).

according to the color "richness" of the visual environment.

To evaluate how faithful the concealment texture is to its visual environment, we placed the concealment texture in the visual environment, at the exact same position as that of the sample used for the macro-texture model. It is a purely qualitative and subjective evaluation, since we have no quantitative and objective metrics in line with our need (Section 5).

The results in an application of substitution demonstrates that the proposed method can synthesize a texture using only simple forms and a few colors, with the same visual aspect as its environment (Figure 3). It is indeed difficult to see the difference between the textures. These results demonstrate the two rules defined: "having the same dominant colors" *and* "having the same dominant forms". We still have to keep in mind that our goal here is not to synthesize a texture exactly the same as a given visual environment; the purpose of a concealment texture is to be both generic enough to be placed at different positions in a scene, and accurate enough to be efficient, at different scales. So our goal is a trade-off between genericity and efficiency.

A way to evaluate the concealment texture in terms of colors and forms is to process the original image and the image with concealment textures with a Gaussian filter and a Sobel filter (Figure 4) and visually comparing the results. Indeed, processing an image with a Gaussin filter gives an overview of its dominant colors; and processing an image with a Sobel filter gives an overview of its dominant forms, by extracting the edges. This way we can subjectively evaluate if the image with a concealment texture has the same dominant colors and forms as the original image (Figure 4).

The results for an application of substitution prove that SCOTT synthesizes a texture not very *salient*. For a concrete application of concealment (Section 4), the results of simulation prove that SCOTT synthesizes a concealment texture which can be placed at different positions in a given visual environment, in order to conceal different objects. SCOTT *is* then a good trade-off between genericity and efficiency.

4 APPLICATIONS

SCOTT may be used in various applications. The initial application of SCOTT is the concealment of objects to reduce visual pollution (Dandumont, 2013): antenna, electrical cabinets, distributor boxes, repeater shelters, etc. Results of simulation show that SCOTT is really efficient by synthetizing a unique concealment texture which makes different objects

Figure 3: The concealment two-level texture is faithful to the visual environment, *while* having simple forms and only a few colors. In the left column is an original image from which have been extracted two samples for the concealment texture synthesis, i.e. the macro-texture and micro-texture models. In the middle column is the same image with the first input sample replaced by the corresponding concealment two-level texture. Since the position of those samples is not given in these images, the results show that it is almost impossible to notice any difference between the original image and the one with the concealment texture. The position of the concealment texture is only revealed in the right column. An interesting exercise is to make someone, unaware of such an application of concealment, watch only the images in the left and middle columns to prove that the concealment texture is unnoticeable.

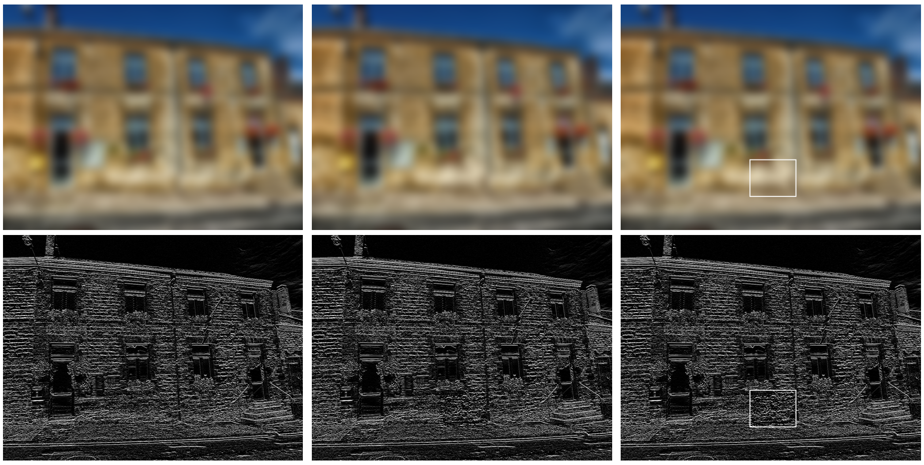


Figure 4: The concealment two-level texture is faithful to the visual environment *because* its dominant colors and forms do not create artificial saliency. In the left column an original image has been processed with a Gaussian filter (top row) and a Sobel filter (bottom row). In the middle columns the same image with a concealment texture (at the exact same position as that of the macro-texture model) has been processed with the same filters. A qualitative comparison between the original images and the same image with a concealment texture shows that the concealment texture has the same dominant forms and colors as its environment. That is why it does not create any artificial saliency.

much less *salient* (Figure 5). To make the simulation simple and fast, the concealment texture has been computed and placed in the image, superimposed on the objects to conceal in the image, and then does not fit their shapes and orientations.

To have a clear idea of what such a concealment would be in a concrete case, we conducted a more sophisticated simulation of a concealment using SCOTT-synthesized concealment texture. Even if the "polluant" is quite big, the concealment texture makes it much less salient by giving it an aesthetically more pleasing look. Once again, by processing the images with a Gaussian filter and a Sobel filter, we can qualitatively evaluate the performance of SCOTT as it decreases the *saliency* of the concealed object (Figure 7).

Another application for SCOTT is *inpainting* (Bruno et al., 2000), which consists in repairing a "hole" in an image. Then the results are the same as in the case of concealment application. A SCOTT-based *inpainting* application could be useful, for example, in 3D video-mapping technology.

Finally, since SCOTT synthesizes a texture which has the same visual aspect as its environment, while having simple forms and only a few colors, SCOTT could be used in an image compression process, when only a few details are needed in somes textures: video games, etc.

5 FUTURE WORK

The results of simulation prove that the concealment is qualitatively and subjectively efficient. But we

(a) (b) (c)

Figure 5: The initial application of SCOTT is the concealment of objects. SCOTT takes two models from a visual environment (a) and synthesizes a concealment two-level texture. A same texture can conceal several different objects (b). The concealed objects are hardly detectable because they are not salient anymore (c).

Figure 6: SCOTT makes the visual pollution much less salient. In a concrete case of applying a SCOTT-synthesized concealment texture (middle column), a realistic simulation makes any big “polluant” (left column) much less salient by giving it an aesthetically more pleasing look (right column).

presently have no quantitative and objective metrics to evaluate its visual impact. Such metrics would automatically reproduce the subjective assessment of a viewer in front the visual environment contraining the SCOTT-synthesized concealment texture. Some metrics actually exist to evaluate the visual *similarity* between two images, like **SSIM** (“Structural SIMilarity”) (Wang et al., 2004), which is usually used to measure the visual *quality* of an image with distorsions, based on an initial distorsion-free image as reference. Even if SSIM is based on the Human Visual System (HSV), by considering image degradation as perceived change in structural information, it is only applied on the luma, and then does not reproduce the entire behavior of the HVS. Futhermore, it is not applicable in our application for two reasons: first SSIM is applied on the entire images, so the smaller the concealment texture, the better the SSIM value; secondly, it goes against our goal since the concealment *is* to modify the input image structure to make an object less salient, then the SSIM value would always be small.

The future work will then be the conception of an objective estimator, based on a HVS model, which would analyze the scene containing the concealment texture. A lead is the use of a “saliency map”, which reveals what is salient to the HVS, i.e. what catches the attention of an observer in front of a given scene. Since the purpose of the concealment texutre is to make an object unnoticeable, a saliency map, correctly based on the HSV response, would reveal that the concealment textures in the resulting images (Figure 6) are not salient, i.e. they would catch no one’s attention.

6 CONCLUSIONS

Based on the Human Visual System, we propose an original method of concealment texture synthesis:

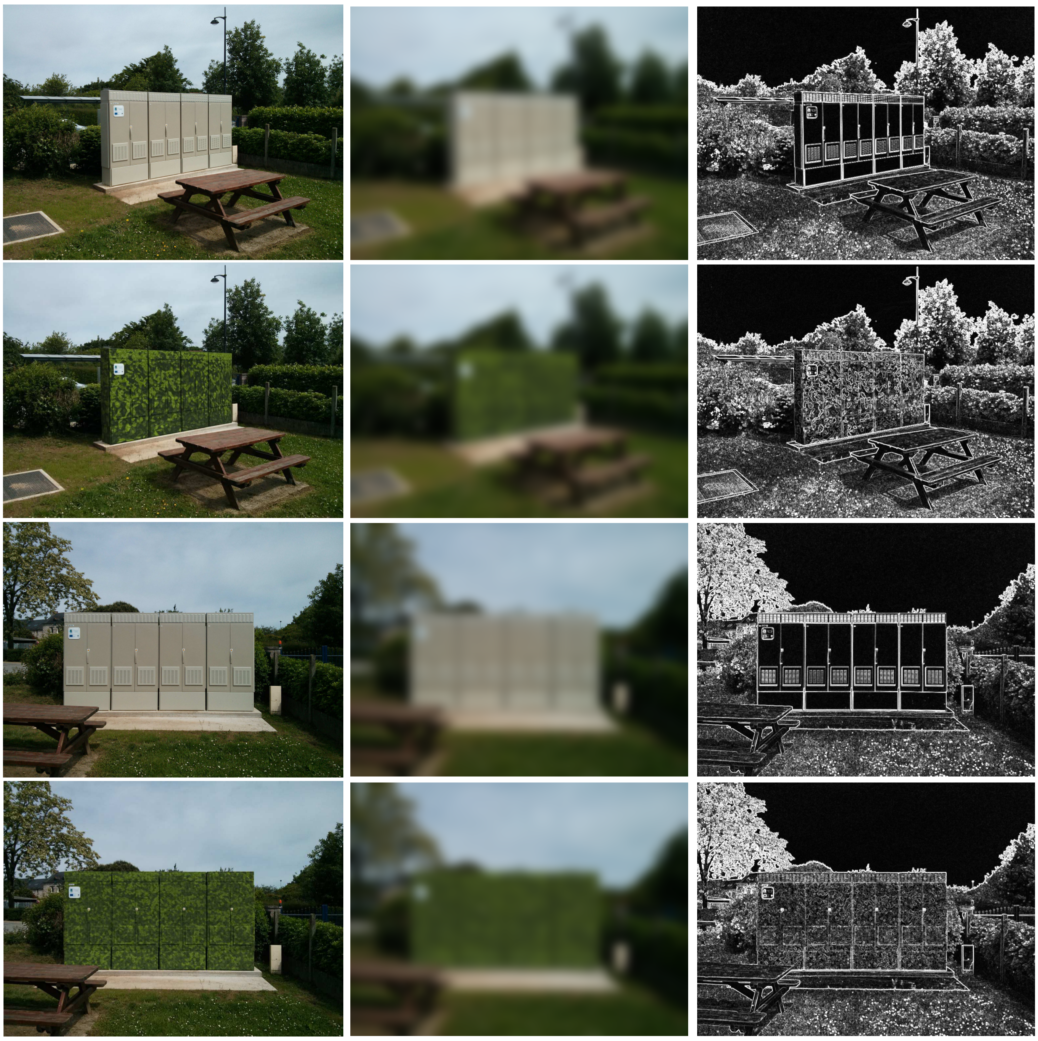


Figure 7: SCOTT uses the dominant colors and forms of the environment. In a realistic simulation, when we process the original image of a visual environment, and its version with the concealment texture (left column) with a Gaussian filter (middle column) and a Sobel filter (right column), we can qualitatively conclude that the concealed object is less salient *because* it has the same dominant colors and forms its environment. Indeed it is more difficult to detect the “polluting” with the concealment texture (first and third rows) than without the concealment texture (second and fourth rows).

SCOTT (“Synthesis of COncealment Two-level Texture”).

The results prove that the concealment texture is efficient, even if it is made of simple forms with only a few final colors; besides, a same concealment texture can be used to conceal several different objects.

Next step will be to conceive an objective measure to evaluate our results, by taking into account the HVS response to them. This will give us a feedback on our work.

Besides, an application of image compression could make use of such a texture synthesis method, by replacing non-salient samples by substitute textures, in a given image.

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